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Proops et al.

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[54] **METAL WORKING**

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[30] **Foreign Application Priority Data**

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[52] **U.S. Cl.** **72/69,** 72/84, 72/86, 72/110

[51] **Int. Cl.** **B21h 1/00**

[58] **Field of Search** 72/69, 84, 86, 87, 72/107, 110

[56] **References Cited**

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[57] **ABSTRACT**

A method of increasing the thickness of a zone of a thin-walled metal member of circular cross-section comprising: heating the metal in the zone to a temperature at which it can be plastically deformed, and applying axial force to the metal in the zone by a first surface which makes rolling engagement with the member and which moves relatively to the member around the circumference of the member, while also applying radial restraint by further surfaces which make rolling engagement with the member so as to locate the thickened metal relatively to the remainder of the member.

5 Claims, 7 Drawing Figures

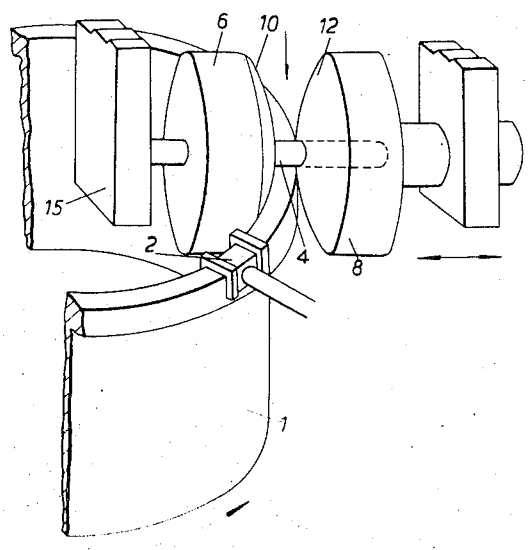


FIG.1.

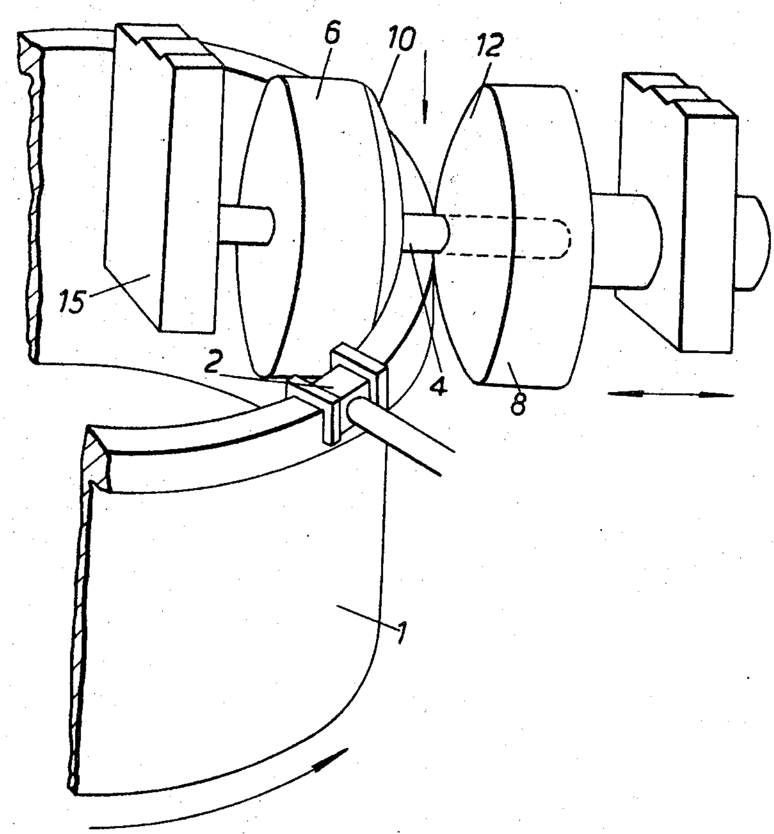
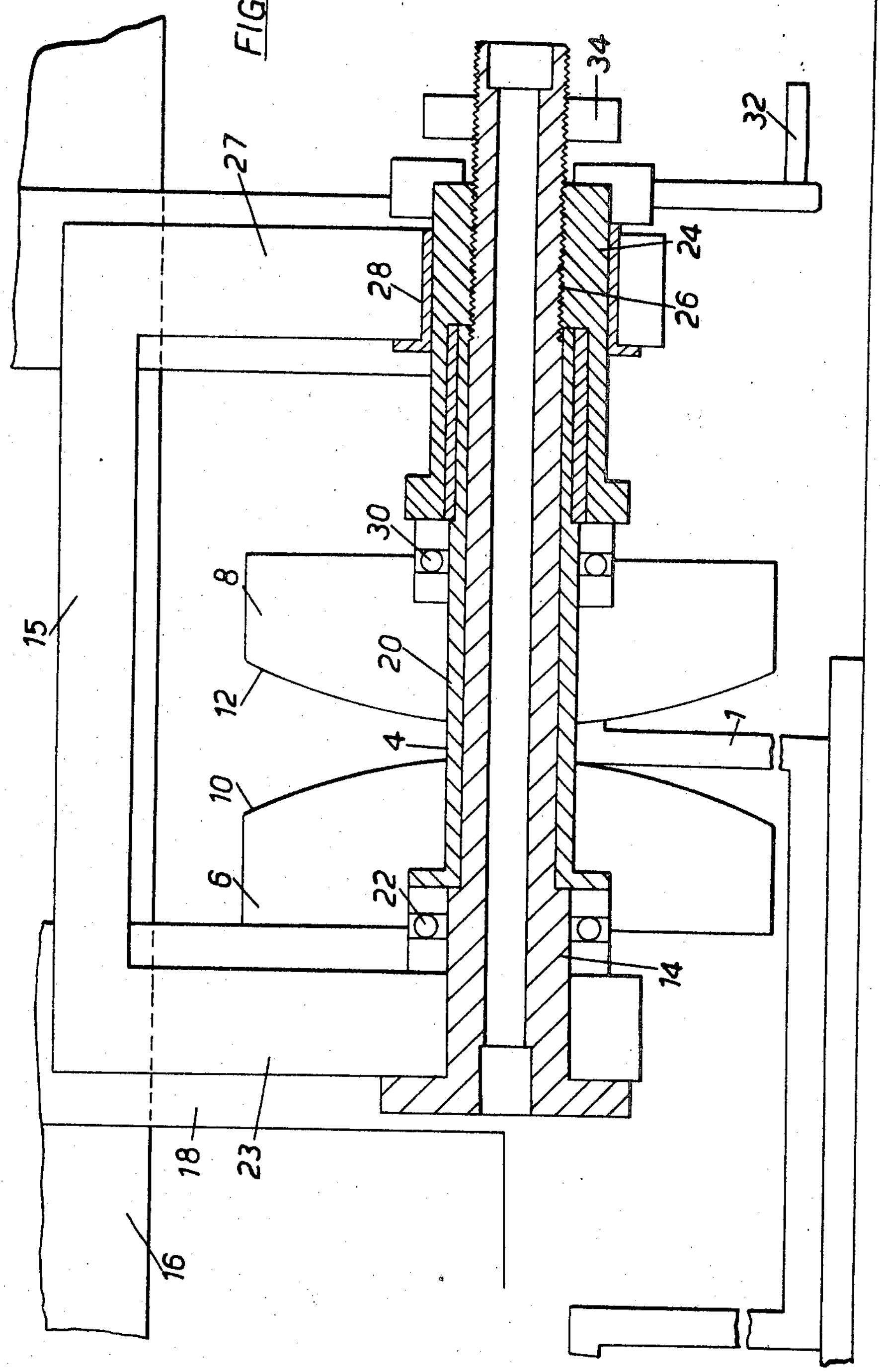


FIG.2



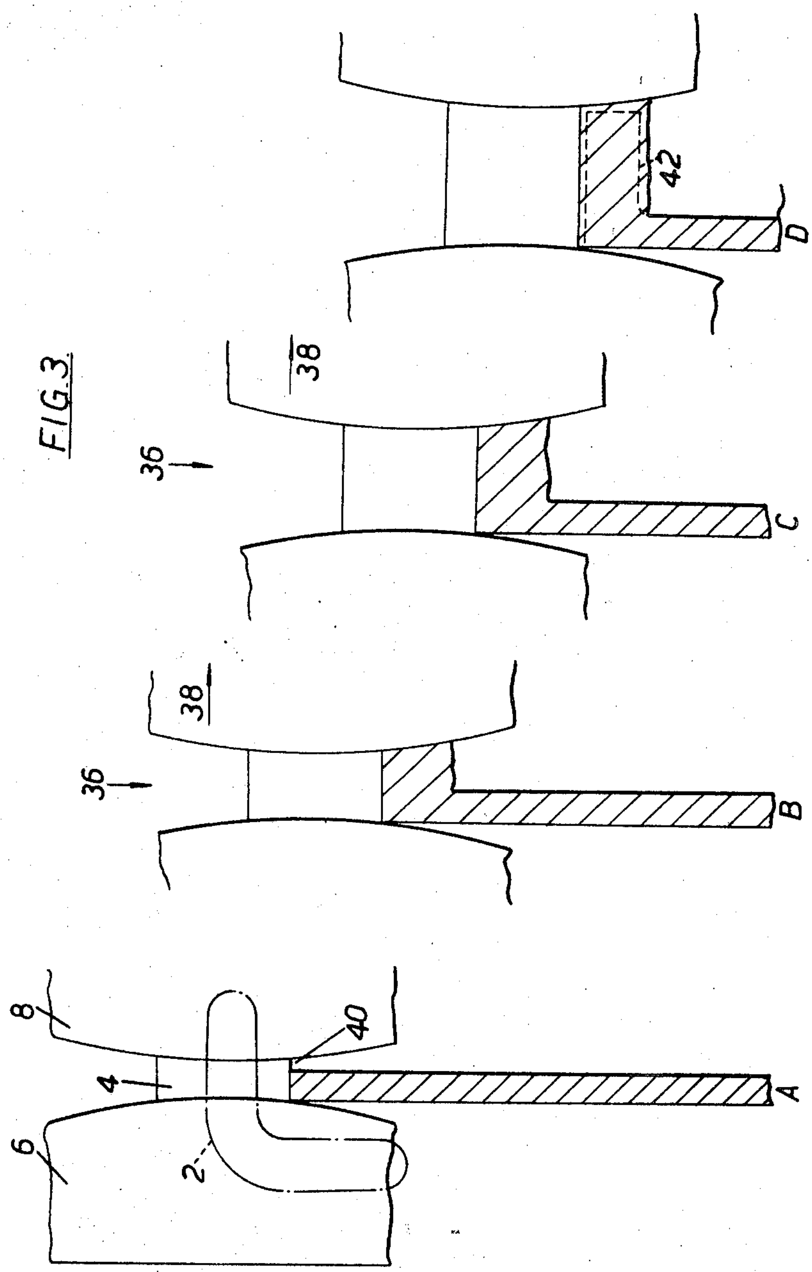


FIG.3

FIG. 4.

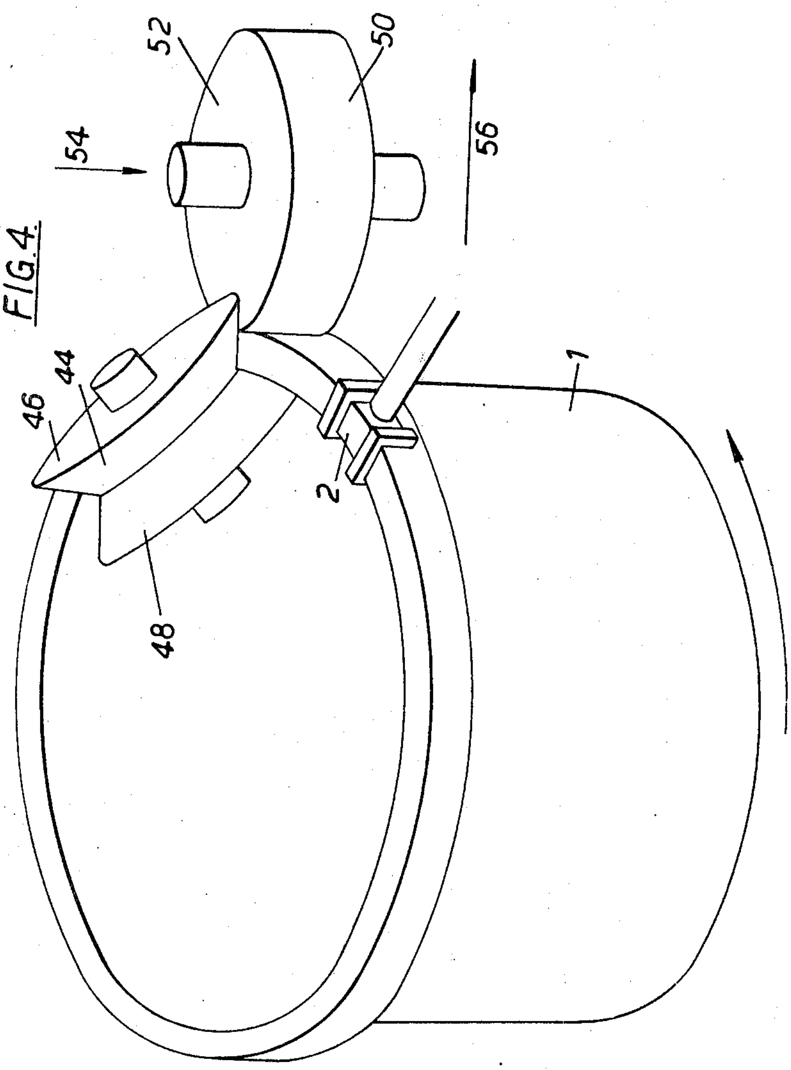


FIG.5.

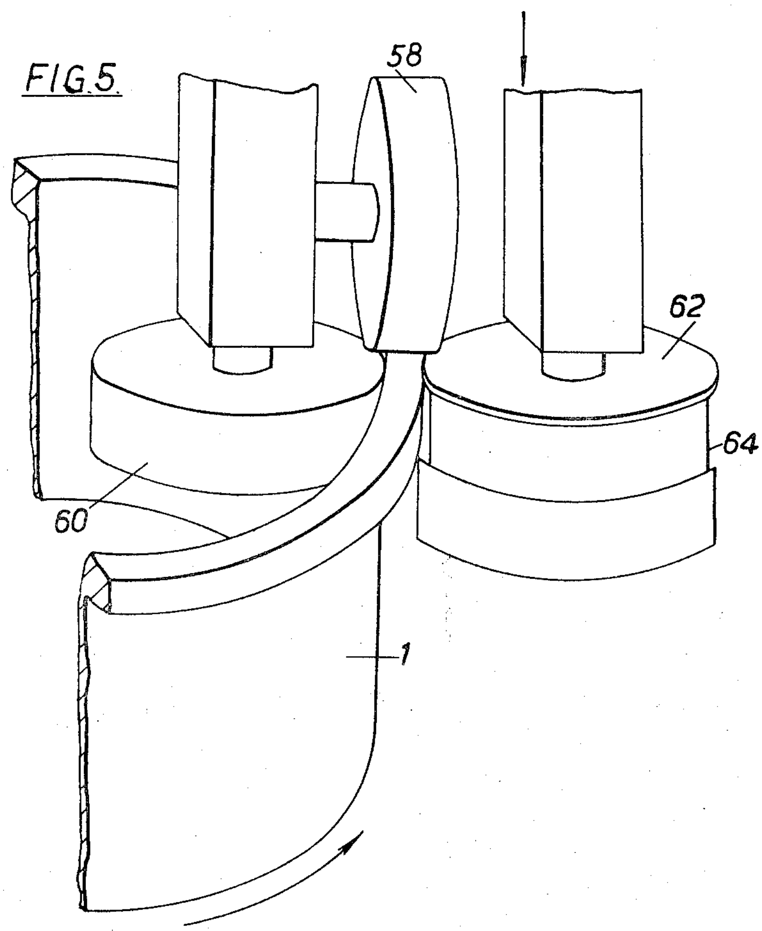


FIG.6.

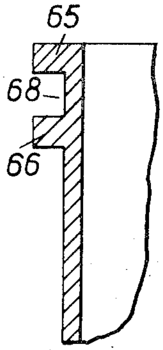
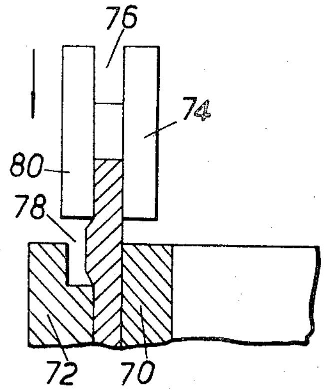


FIG.7.



METAL WORKING

Gas turbine engines for aircraft include components which are fundamentally cylindrical or conical in shape, of large diameter, and with a wall which is thin in relation to the diameter. These components are required to have additional metal at one or more zones. For example, flanges may be required at the ends, to permit a component to be connected to another one. There may be a need to provide a pair of circumferential flanges, to define between them a groove to receive a sealing member.

The present invention concerns a method by which such components can be made from an integral blank, without the need to remove very large quantities of metal from the blank.

According to this invention a zone of the end or edge of a thin-walled metal member of circular cross-section in increased in thickness by heating the metal in the zone to a temperature at which it can be heating the metal in the zone to a temperature at which it can be plastically deformed, and applying axial force to the metal in the zone by a first surface which makes rolling engagement with the member and which moves relatively to the member around the circumference of the member, while also applying radial restraint by further surfaces which make rolling engagement with the member so as to locate the thickened metal relatively to the remainder of the member.

The metal member may be a tubular blank which has been produced from a piece of sheet metal, rolled into a cylinder or cone, with a butt-welded longitudinal seam.

The present method has many advantages, as compared with the method usually used hitherto, namely forming the majority of the component by rolling up sheet metal, and then adding the necessary flanges, by welding on of annular pieces which have been produced separately as forgings. The advantages include:

1. Material costs are substantially reduced. Expensive flange forgings are replaced by a small increase in sheet metal at low cost.

2. Mechanical strength and reliability are increased by the elimination of difficult welded joints and by improved grain flow.

3. Machining is simplified. Part-machining of forgings prior to welding is eliminated, distortion is reduced and full requiring of flanges can be carried out in unit form.

4. Indirect costs are substantially reduced. There can be reduced stock holding in raw material and part-machined stores, requireing less handling. Fewer jigs and fixtures are necessary. Inspection of part-machined components and large welded joints are eliminated.

It is known to upset ends of pipes by heating the ends and applying pressure to them, but this procedure does not involve rotation and is not applicable to tubular members having large diameters.

Further details of the invention which are preferred, though not essential, will be mentioned in the course of the following description of some particular examples, illustrated by the accompanying drawings, in which:

FIG. 1 is a perspective view of an arrangement of rollers for applying axial force and radial restraint;

FIG. 2 is a vertical section of the same arrangement;

FIG. 3 is a diagram showing, in cross section, successive stages in deformation of an end zone of a tubular blank;

FIG. 4 and FIG. 5 show two alternative arrangements of rollers;

FIG. 6 is a section showing two flanges on a component; and

FIG. 7 is a diagram of an apparatus for forming one of the two flanges shown in FIG. 6.

FIGS. 1 to 3 show the formation of an external flange on one end of a cylindrical tubular blank **1**. The machine used is an ordinary vertical boring machine with minor modifications. The blank is mounted with its axis vertical on the table of the machine, not shown, which can rotate about the axis.

As shwn in FIGS. **1** and **2**, the means for applying downward axial force to the upper end of the blank is a roller **4**, and the means for applying radial restraint is two rollers **6** and **8**, the operative faces **10** and **12** of which are part-spherical. These rollers are on a common axis, and are carried by a non-rotating shaft **14** which is mounted in a bracket **15** on the usual tool slides **16** and **18** of the boring machine.

The roller **4** is constituted by the central part of a sleeve **20** which can turn on the shaft **14**. The roller **6** is fixed to the sleeve and is located by a thrust bearing **22** abutting one arm **23** of the bracket **15**. The roller **8** can shift axially along the sleeve **20** under control of a nut **24** which is threaded at **26** onto the shaft **14**. The nut is journalled in a second arm **27** of the bracket **15**, and contains a bearing **28** for the sleeve **20**. The nut abuts a thrust bearing **30** for the roller **8**. The nut **24** can be turned by a handle **32** and locked by a further nut **34**.

In operation, the table of the machine is rotated, thus rotating the blank **1**. The rollers are shifted horizontally on the slide **16** so as to bring the surface **10** of the roller **6** to a position tangent to the inner cylindrical surface of the blank. Then the rollers are fed downwards on the slide **18** to bring the roller **4** into engagement with the upper end of the blank.

The upper end zone of the blank is heated by a multi-turn induction heating element **2**. This heating element is mounted on the bracket **15**, by means not shown. As shown in FIG. **1**, the heating element extends over an arc of the circumference of the blank, and the rollers occupy a position such that they act on a part of the blank soon after that part has left the heating element. However, to facilitate understanding of the function of the heating element, its position in relation to the blank is indicated in chain lines at **2** in FIG. 3A as if it were not circumferentially offset from the rollers.

For the operation of forming the flange on the blank, the bracket **15** carrying the rollers and the heating element is fed gradually downwards, as indicated by the arrows **36** in FIG. **3**. In addition, by turning the nut **24**, the roller **8** is shifted gradually radially outwards, as indicated by the arrows **38**.

The initial shape of the blank is shown in FIG. 3A. At this stage, there is a radial clearance **40** between the outside of the blank and the roller **8**. The rollers are fed downwards, and when the metal has been deformed so as to fill the clearance **40**, then the outward movement **38** of the roller **8** commences. The metal is progressively deformed, passing through the situations shown in FIGS. 3B and 3C, and the final shape of the blank is as shown in FIG. 3D. A relatively small amount of metal is then machined away to the outline **42**, to produce the final shape of the flange.

In the example shown, the thickness of the material of the blank is 0.2 inches.

The rough dimensions of the flange in FIG. **3D** are 1.0 ins. by 0.5 ins.

The axial travel of the rollers and heater is approximately **2** inches. Larger flanges may be made from the same material.

If the metal is stainless steel, the electric supply to the heating element is adjusted so that the metal is heated to 1120°C.

For a blank measuring 12 inches diameter, a suitable rate of rotation is approximately 11 rpm, and the rate of axial feed of the rollers and heating element is 0.050 inch per revolution. That is to say 40 revolutions are necessary to carry out the process. The metal reaches operating temperature in 10 to 15 secs. from switching on the heater.

The invention can be applied to a wide range of sizes of metal member, from as small as about 4 ins. diameter, to as large as available machinery can handle. The advantages compared with upsetting become less as the diameter decreases to 4 ins. According to the diameter of the member, it is necessary to adjust the position of the heater as seen in plan, so as to be as close to the member as is possible without risk of short circuiting. For small sizes, the roller **6** may be changed for another having apart-spherical surface of smaller radius, since this radius must be smaller than the internal radius of the member.

The roller **8** need not have a part-spherical operative face; this face could be flat.

FIG. **4** shows an alternative arrangement of rollers, which is similar in effect to that shown in FIG. **1**, in that there are three effective surfaces, which engage the top of the flange, and the radially inner and outer surfaces.

Axial force is applied to the upper end of the blank by a surface **44** of a roller **46**, the axis of which is in a radial plane of the blank, inclined to the axis of the blank. Radial restraint is provided by a second surface **48** of the roller **46**, and by a surface **50** of a roller **52**. The roller **52** is cylindrical and its axis is vertical, lying in the same plane as the axis of the roller **46**. The rollers **46** and **52** and the heating element **2** are all fed axially downwards at the same rate, as indicated by the arrow **54**. At the same time, the roller **52** is shifted gradually radially outwards as indicated by the arrow **56**. In FIG. **4**, the inclination of the axis of the roller **46** is shown as 45° to the vertical. The angle depends upon the size of the blank. The angle is chosen to five rolling contact of the roller at all times, and thus the axis of the roller must pass through the inter-section of the axis of the blank and the plane of the top surface of the flange.

In FIGS. **1** and **4**, the bottom surface of the flange is not positively controlled. FIG. **5** shows how control may be applied if desired. In FIG. **5** there are three separate cylindrical rollers **58,60,62**, the axis of **58** being horizontal and the axes of **60** and **62** being vertical in a plane which is radial to the blank **1**. The axis of the roller **58** is parallel to this plane but displaced a little from it, so that the lowest part of the roller **58** does not foul the rollers **60** and **62**.

The roller **62** has a rectangular-sectioned groove **64** in its periphery, into which metal is displaced as the three rollers are fed downwards. The roller **62** does not move away from the roller **60**. That is to say, the radial restraint exerted by the roller **62** only becomes effective towards the end of the operation. If a flange of large radial extent is required, the operation may be in two stages, the roller **62** being replaced for the second stage by a roller having a groove which has a greater radial dimension.

FIG. **6** shows a blank which has been formed with two flanges, namely a terminal flange **65**, and an intermediate flange **66**, which between them define a groove **68** suitable for receiving a sealing element.

The flange **66** is formed first, and a suitable apparatus is shown in FIG. **7**. In this case it is not practical to use induction heating, and resistance heating is used instead. One electrode consists of two concentric cylindrical members **70** and **72**. The other electrode consists of a roller **74** with a groove **76**. The groove **76** serves to accommodate metal which will later be required to form the base of the groove **68**, and to form the flange **64**. In the electrode **72** there is a groove **78**, into which metal is progressively deformed as a result of the application of axial pressure by means of the roller **74**. This axial pressure procuces the intermediate flange **66**. The metal of the flange is restrained both by the bottom and outer wall of the groove **78**, and also by the flange **80** of the roller **74**.

After the intermediate flange **66** has been completed in this way, the electrode components **70** and **72** are removed, and then the end flange **64** is formed in the same way as shown in FIGS. **1** to **3**.

We claim:

1. A method of producing at one end of the wall of a thin-walled metal member of circular cross section, a zone of greater thickness than the wall of the member, comprising the steps of:

a. locally heating successive parts of the circumference of the end of the member to a temperature at which they can be plastically deformed, by causing relative movement between a source of heat and the circumference of the member,

b. deforming the metal solely by applying axial force to that part of the circumference of the end of the member which at any instant is heated, by means of a first surface which makes rolling engagement with the member and moves relatively to the member around the circumference of the member, and

c. applying radial restraint by means of further surfaces which make rolling engagement with the member so as to locate the thickened metal relatively to the remainder of the member, the first surface at its instantaneous place of contact with the member being always tangent to a plane perpendicular to the axis of the member, and the deformation of the metal being progressive, starting at the end of the member.

2. A method according to claim **1**, including the further step of progressively increasing the spacing between said further surfaces during said deforming of the metal.

3. Apparatus for producing at one end of the wall of a thin-walled metal member of circular cross section, a zone of greater thickness than the wall of the member, comprising a support for the member and a mounting, means for relatively rotating the support and the mounting about an axis, a first roller surface carried by the mounting and adapted to apply axial force to the member, means for relatively moving this first roller surface towards the support, a second roller surface and a third roller surface both carried by the mounting and adapted to engage the inner and the outer faces of the zone respectively at a common station, means for shifting the second and third roller surfaces relatively to each other in a direction perpendicular to the axis of relative rotation of the support and the mounting, and means on the mounting adjacent to the first roller for locally heating the end of the wall of the member.

4. Apparatus according to claim **3** in which the first, second and third roller surfaces are rotatable on the mounting about a common axis.

5. A method of producing at an edge of a metal member of circular cross section, a zone of greater thickness than the body of the member, comprising the steps of:

a. locally heating successive parts about the circumference of said edge to a temperature at which said parts can be plastically deformed, by causing relative movement between a source of heat and the edge of said member,

b. deforming the metal at said edge solely by applying a deformation force perpendicular to said edge and normal to the direction in which said thikening is to be effected at that part of the circumference of said edge which at any instant is heated, by means of a first surface which makes rolling engagement with the edge of said member and moves relative to said edge around the circumference thereof, and

c. applying a restraining force in a direction normal to said deformation force in said direction of thickening by means of further surfaces which make rolling engagement with said member so as to locate the thickened metal relative to the remainder of the member, the deformation of the metal being progressive starting at the edge of said member.

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